GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

no action
OAL

Date: August 9, 1977

Project Title: Analysis of Field Coil Failure

Project No: A-760-206

Project Director: Mr. James L. Hubbard

Sponsor: U. S. Army Engineer District, Mobile; Corps of Engineers

Agreement Period: From 8/5/77 Until 9/1/77

Type Agreement: P. O. No. DACW01-77-M-9462

Amount: $2,000

Reports Required: Final Report

Sponsor Contact Person (s):

Technical Matters

Contractual Matters
(thru OCA)

U. S. Army Engineer District, Mobile
Corps of Engineers
ATTENTION: SU-C
P. O. Box 2288
Mobile, AL 36628
(202) 690-2531

Defense Priority Rating: None

Assigned to: Applied Sciences Laboratory (School/Laboratory)

COPIES TO:

- Project Director
- Division Chief (EES)
- School/Laboratory Director
- Dean/Director—EES
- Accounting Office
- Procurement Office
- ✓ Security Coordinator (OCA)
- Reports Coordinator (OCA)
- Library, Technical Reports Section
- Office of Computing Services
- Director, Physical Plant
- EES Information Office
- Project File (OCA)
- Project Code (GTRI)
- Other

CA—3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

no action
ADB

Date: January 10, 1978

Project Title: Analysis of Field Coil Failure

Project No: A-760-206

Project Director: Mr. James L. Hubbard

Sponsor: U. S. Army Engineer District, Mobile; Corps of Engineers

Effective Termination Date: 9/1/77

Clearance of Accounting Charges: 9/1/77 (Fixed-Price)

Grant/Contract Closeout Actions Remaining:

X Final Invoice

_ Final Fiscal Report

_ Final Report of Inventions

_ Govt. Property Inventory & Related Certificate

_ Classified Material Certificate

_ Other _____

Assigned to: Applied Sciences Laboratory (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)
Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other _____

CA—4 (3/76)

TECHNICAL REPORT

PROJECT NO. A 760-206

FAILURE ANALYSIS OF A HYDROELECTRIC GENERATOR STRAP FIELD COIL

By

JAMES L. HUBBARD

P.O. NO. DACW01-77-M-9462

SEPTEMBER 1977

SPONSORED BY

U. S. ARMY CORPS OF ENGINEER
U. S. ARMY ENGINEER DISTRICT, MOBILE
MOBILE, ALABAMA 36628

Prepared by
ANALYTICAL SERVICES BRANCH
ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

INTRODUCTION

The hydroelectric generator strap field coil which was submitted to the Analytical Services Branch of the Engineering Experiment Station of Georgia Tech on August 5, 1977, for failure analysis has been examined using a variety of analytical techniques. This crossed coil had failed by electrical burn out which completely melted away the corner area of two turns near the bottom connector as shown in Figure 1. The results of this analysis indicate no material defects in the coil and have not shown cause for this failure.

EXPERIMENTAL PROCEEDURE

The coil was first examined in the as received condition for any visible clue such as obvious defects, unusual coloration, and condition of the insulation. A "tongue" of material was observed on the side of the burn out area nearest the connector, see Figure 2, which appeared unusual. A portion of the last turn including the connector and the "tongue" was removed from the coil for closer examination. The "tongue", as shown in Figures 3 and 4, was then identified as being the result of the failure of the silver brazed joint which is present in this area as shown in detail GR4 of the Westinghouse blue print No. 7149D78. The "tongue of material was removed from the main body and a portion of the brazed surface cut out for examination in the scanning electron microscope (SEM). This surface was anlyszed in the SEM using an energy dispersive x-ray analyzer and all areas checked showed elements consistent with the elemental content of Sil Fos braze with perhaps an excess of

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

September 19, 1977

Mr. Roy Harvison
OS & Unit, U. S. Army Engineer District, Mobile
Mobile, Alabama, 36628

Dear Mr. Harvison:

Enclosed is the report on the failure analysis of the field coil. I regret that I have not been able to show cause for the failure. If any new leads arise I would appreciate your letting me know and perhaps our lab may be of further assistance to you.

Sincerely,

James L. Hubbard
Senior Research Scientist

JLH:cni

phosphorous in some areas. This analysis, however, indicates that the joint was properly brazed and failed as a result of the remelting of the braze due to the heat of the electrical failure and was probably not a factor in the main failure cause.

The copper material itself was suspect and the condition of the burn out corner in a questionable mechanical state due to the lack of first hand knowledge of the amount of deformation, if any, which it may have been given during attachment of the connector. In order to check the material and the possibility of microcracks after deformation, the remainder of the last half turn from which the connector corner had already been removed was pried loose from the coil. The short tapered end was placed in a vice and the corner bent approximately 30° and rebent to its original position. A section was taken from the center of the turn which was mounted, polished, and etched. This etched section was then studied with an optical microscope. The structure, as shown in Figure 5, appears normal and no microcracks were evident.

Further examination of the coil revealed that a large amount of material which melted at the corner had run down and resolidified between the mica insulation and the inner surface of the coil. A few pieces of this material were removed and analyzed in the electron probe microanalyzer in the hope that any trace elements found might give a clue as to the cause of failure. The results of this analysis is given in Table I.

TABLE I

Elemental Analysis of Resolidified Copper Surfaces

Element	Approximate Amount (%)	Comments
Al	0.1 - 0.3	in spots
Si	0.3 - 0.8	in spots
S	0.3 - 0.5 overall with some areas 4-6	
Ca	0.2 - 0.6	in spots
Mn	trace	
Fe	0.2 - 0.7 overall with some areas 3-5 and some 100%	
Mo	trace	in spots

Some of the melted material was sectioned to facilitate analysis of its interior. The only elements which seem to have reacted with the molten copper were Si, S, and Fe. Si was found in spots ($\sim$ 0.5%), S was found overall ($\sim$ 0.5%) with some "hot spots" containing $\sim$ 2% and Fe was found overall ($\sim$ 0.5%) with some "hot spots" containing $\sim$ 5-10%.

The source of the sulfur was not obvious which lead to the analysis of the materials in contact with the resolidified copper. A piece of mica, some epoxy, and some of the red material used to pack the uneven ends of the coil were analyzed. The mica and epoxy analyses gave expected results. The analysis of the red material is given in Table II.

TABLE II

Analysis of Red Packing Material

Element	Approximate Amounts (%)
Si	2 - 3
P	0.1 - 0.5

TABLE II con'td

Analysis of Red Packing Material

Element	Approximate Amounts (%)
S	12 - 15
Ca	5 - 10
Mn	∿ 0.5
Fe	8 - 10

It appears reasonable from this analysis that the sulfur in the melted and resolidified copper came from a reaction with the red packing material. This material could also account for the iron in the copper except for the few "hot spots" of high iron concentration which was found to contain no sulfur.

CONCLUSIONS

This analysis has shown that the copper coil has probably reacted with some iron during the failure. While it is obvious by inspection of the coil that arcing has occured between the coil and the pole piece, it is believed that the iron found in the melted and resolidified copper which ran between the mica and the coil away from the arc over region would indicate a reaction of the copper with some iron part early in the time span of the failure. However none of the analyses has revealed a possible cause for failure initiation.

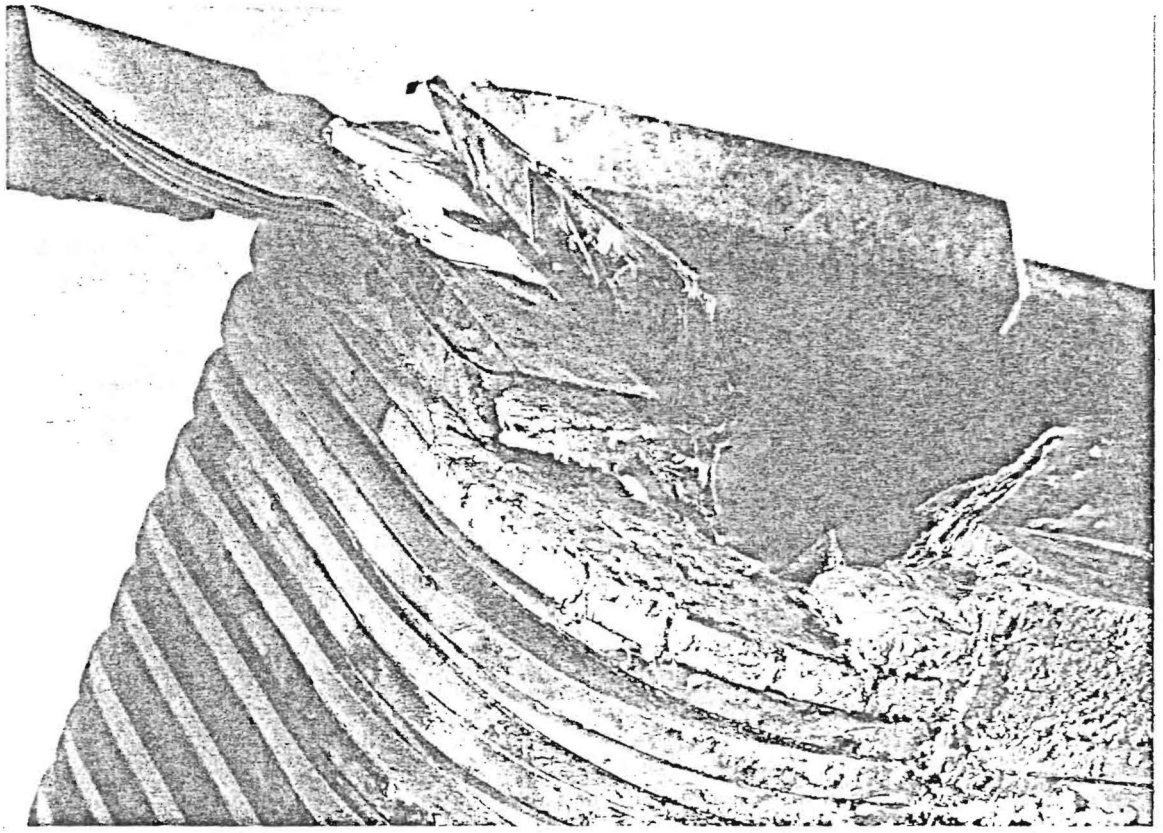

Figure 1: Burned coil

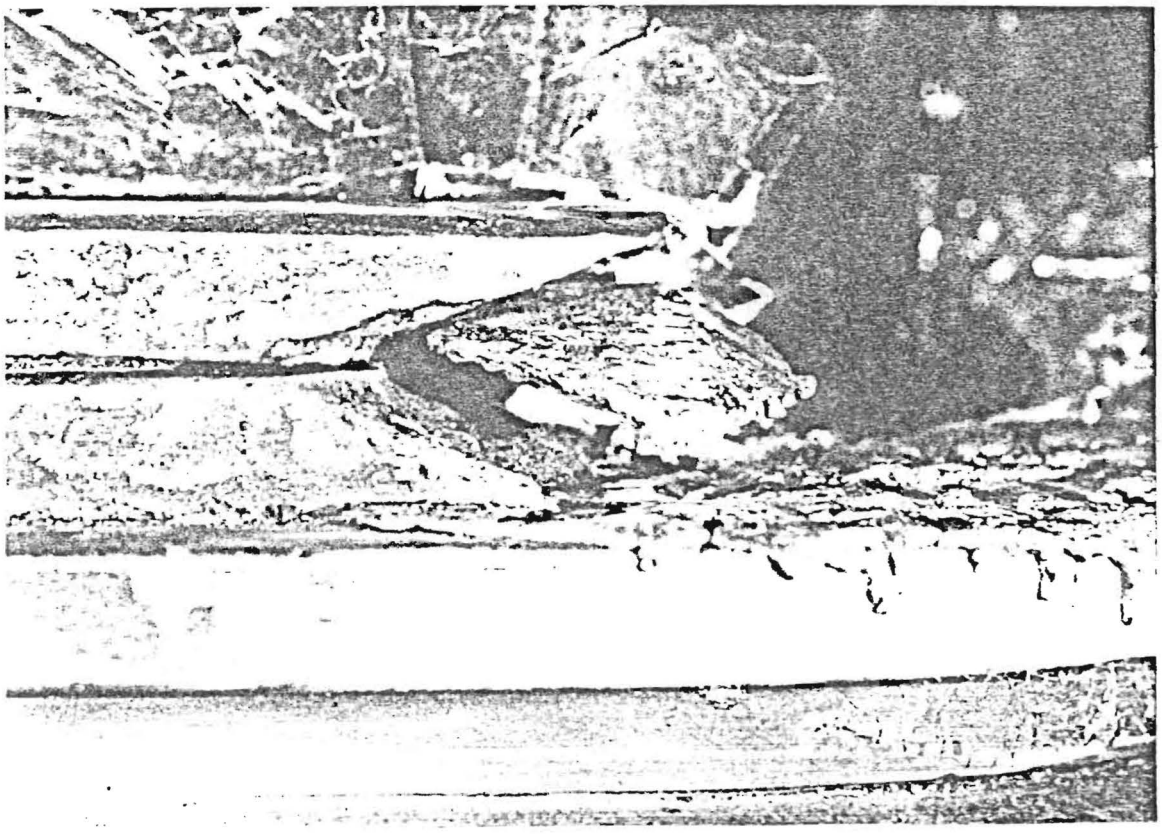

Figure 2: "Tongue" at edge of burn out

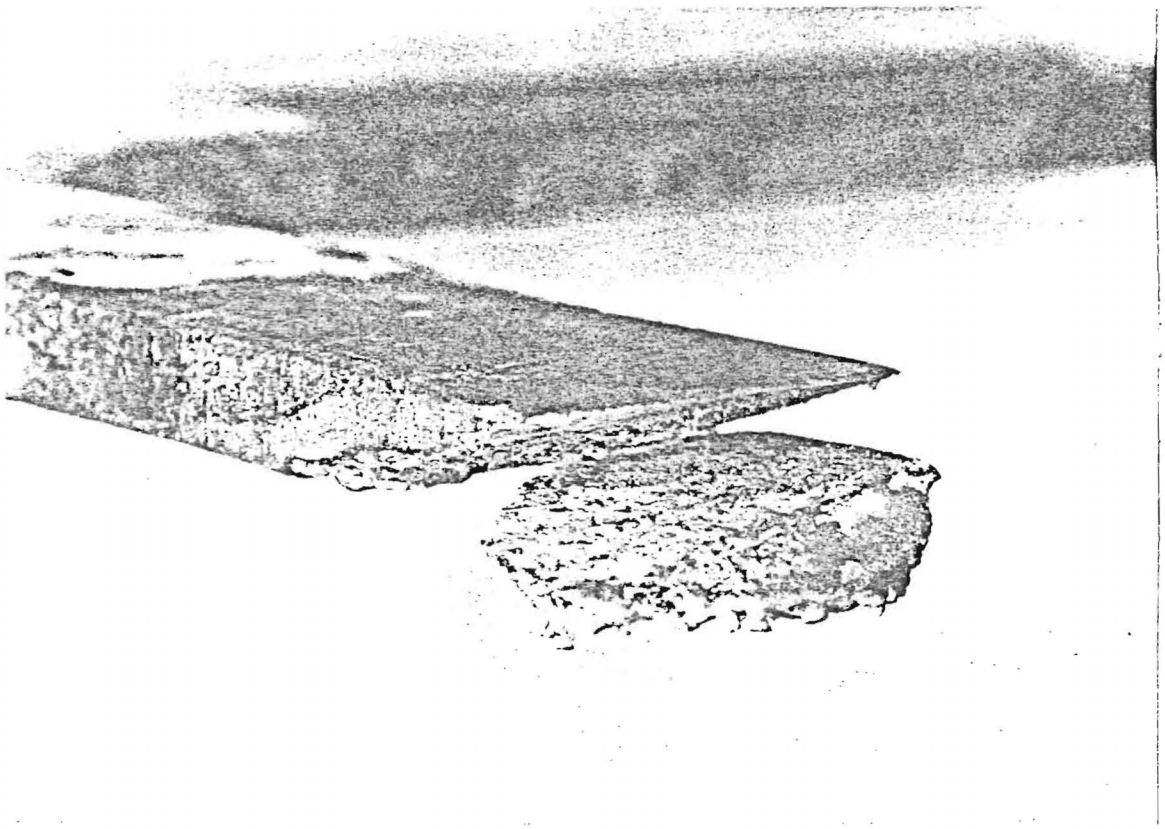

Figure 3: Connector Corner with "tongue"

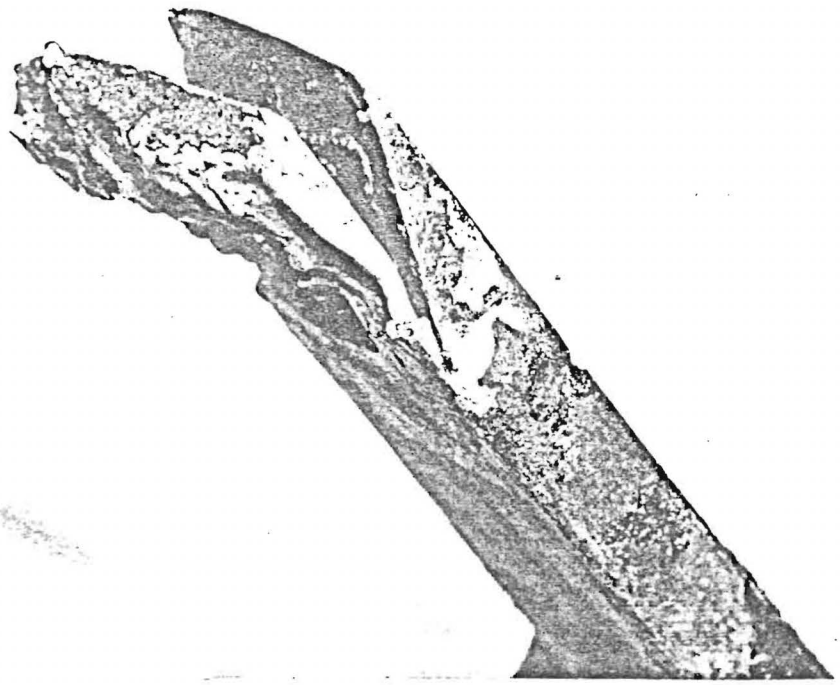

Figure 4: "tongue"

Figure 5: Copper structure (150X)